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# Resolving the pulsations of the subdwarf B star KPD 2109+4401

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**ABSTRACT**

We present the results of extensive time series photometry of the pulsating subdwarf B star KPD 2109+4401. Our data set consists of 29 data runs with a total length of 182.6 hours over 31 days, collected at five observatories in 2004. These data are comprised of high signal-to-noise observations acquired with larger telescopes and wider time coverage observations obtained with smaller telescopes. They are sufficient to resolve the pulsation structure to 0.4 $\mu$Hz and are the most extensive data set for this star to date. With these data, we identify eight pulsation frequencies extending from 4701 to 5481 $\mu$Hz, corresponding to periods of 182 to 213 s. The pulsation frequencies and their amplitudes are examined over several time-scales with some frequencies showing amplitude variability.

**Key words:**
Stars: oscillations – stars: variables – stars: individual (KPD 2109+4401) – Stars: subdwarfs

## 1 INTRODUCTION

Subdwarf B (sdB) stars are low-mass ($\sim 0.5\,M_\odot$) core helium-burning horizontal branch stars with very thin outer hydrogen layers, making them quite hot; they likely proceed directly to the white dwarf cooling track without reaching the asymptotic giant branch after core helium exhaustion (Heber 1984; Saffer et al. 1994). In recent years, over 30 sdB stars have been identified as multimode pulsators, with typical pulsation periods of 100–250 s and amplitudes generally less than a few hundredths of a magnitude. Officially designated V361 Hya stars, they are also commonly known as EC 14026 stars after the prototype (EC 14026-2647) and referred to as sdBV stars following the pulsating white dwarf convention (DOV, DBV, DAV). Recent reviews of pulsating sdB stars have been given by Charpinet, Fontaine & Brassard (2001; pulsation theory) and Kilkenny (2002; observation).

Asteroseismology has successfully been applied to some other classes of variable stars in order to discern their interior conditions (Winget et al. 1991; Kanaan et al. 2005; Mukadam et al. 2003; among others) and in time, it is hoped the same can be accomplished for sdB stars. To do so, the pulsation frequencies (periods) must first be resolved. Variable star discovery surveys seldom resolve or detect the complete set of pulsations. Multisite campaigns, because of the complexity of organization, have only observed a few sdB pulsators. Our program is to resolve poorly-studied sdB pulsators from single-site data, supplemented with a small amount of multi-site data. This method has proven useful for the sdBV star Feige 48 (Reed et al. 2004). By combining limited (5–10 days) amounts of data from larger telescopes with a longer timebase (some 20+ days) of data from smaller (0.4–1.0m) telescopes, it is possible to effectively resolve the pulsation spectrum of an sdBV star. Our high signal-to-noise (S/N) data from larger telescopes can detect pulsation amplitudes as low as 0.2 milli-modulation amplitudes (mma, equivalent to 0.02%), insuring that we do not miss low amplitude modes and that the resolution of our complete data set is 0.4 $\mu$Hz.

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This paper reports the results of our observations on the sdBV star KPD 2109+4401 (hereafter KPD 2109). KPD 2109 was discovered to be a pulsator nearly simultaneously by Koen (1998; hereafter K98) and Billéres et al. (1998), both of whom detected five frequencies. Additional studies of KPD 2109 include a time-series spectroscopic study (Jeffery & Pollacco 2000) and multicolour observations using ultracam on the WHT 4.2-m telescope (Jeffery et al. 2004). However, none of these relatively short duration observations have likely resolved the pulsation structure (in fact, K98 claim not to have), prompting us to choose KPD 2109 for follow-up observations.

## 2 THE OBSERVATIONS

Data were collected at five observatories during September and October of 2004 with CCD photometers and the specifics of each run are provided in Table 1. Data were obtained at the McDonald observatory 2.1 m telescope and the MDM observatory 1.3 m telescope using an Apogee Alta U47+ CCD camera. This camera is connected via USB2.0 for high-speed readout and our binned ($2 \times 2$) images had an average dead-time of one second. Observations at Baker Observatory (0.4 m) were obtained with a Princeton Instruments RS1340 CCD camera. We used a $601 \times 601$ pixel subframe at $1 \times 1$ binning and our average dead-time was one second. Data from the Observatory of the University of Athens (0.4 m) were obtained with an SBIG ST-8 CCD camera with an average dead-time of six seconds. Photometry from Mt. Suhora Astronomical Observatory, Poland (0.6 m) were obtained with an SBIG ST-10 XME CCD camera with an average dead-time of three seconds. The observations at MDM, McDonald, and Baker observatories used red cut-off filters (BG38, BG40, and BG40, respectively), Suhora observatory observations used a Johnson B filter, and data from Athens used no filter. As pulsations from sdB stars have little dependence in the visual between these various filters, and no phase dependence (K98), mixing these data is not seen as a problem. The same is true for timing from the various observatories: NTP was used at Athens, McDonald, Baker, and MDM observatories and a GPS clock at Suhora observatory. Both of these issues (particularly timing) would also appear as artifacts in our analyses in §3 and 4.3. A portion of data from MDM observatory is shown in Figure 1 on two different scales. The top panel has several hours of data, showing the obvious beating that occurs on multiple time scales which indicates the multiperiodic nature of the pulsations. The bottom panel spans less time to emphasize individual pulsations.

The standard procedures of image reduction, including bias subtraction, dark current and flat field correction, were followed using IRAF packages. Differential magnitudes were extracted from the calibrated images using MOMF (Kjeldsen & Frandsen 1992). Observations acquired at MDM observatory generally had photometric conditions while others were through light clouds or transparency variations. As sdB stars are substantially hotter, and thus bluer, than typical field stars, differential light curves, even using an ensemble of comparison stars, are not flat due to differential atmospheric and colour extinctions. A low-order polynomial was fit to remove these trends from the data on a night-by-night basis.

**Table 2.** Subgroups used in pulsation analysis.

| Group | Dates (2004) | Telescope(s) | Res. ($\mu$Hz) | Limit (mma) |
|---|---|---|---|---|
| I | 12 Sept. - 14 Oct. | All | 0.4 | 0.38 |
| II | 19 Sept. - 14 Oct. | Bak + MDM | 0.5 | 0.38 |
| III | 14 Sept. - 17 Sept. | McD+Suh | 3.5 | 0.67 |
| IV | 19 Sept. - 3 Oct. | Bak | 0.8 | 0.83 |
| V | 5 Oct. - 14 Oct. | MDM | 1.3 | 0.29 |

## 3 THE FREQUENCY CONTENT OF THE OBSERVATIONS

Due to the length of our campaign we grouped combinations of nightly runs into the sets given in Table 2 for the convenience of analyses. Because the Athens data was sufficiently noisier than other data, it was only included in Group I. The last two columns of Table 2 give our frequency resolution and detection limit as calculated using the methods of Breger et al. (1994). The detection limit serves as the limit below which pulsations cannot be considered significant compared to the noise. We analyzed these data in the usual manner (Kilkenny et al. 1999) which involves examining subgroups of data for consistency. This also allowed us to examine variations in amplitude over the course of our run and look for systematic differences in phase or timing between observatories (none were detected). Temporal spectra and window functions for the groups are plotted in Figure 2. A window function is a single, noise-free sine wave (of arbitrary amplitude) sampled at the same times as the data. The central peak of the window is the input frequency with other peaks indicating the aliasing pattern of the data. Frequencies, amplitudes and phases were determined by simultaneously fitting a nonlinear least-squares solution to the data. Our solutions for the frequencies for all groups as well as those discovered by K98 are provided in Table 3. We also calculated a noise-weighted FT for the Group I data, but do not show it as there was no improvement. This indicates that the majority of our data are quite good quality, with the noisy runs not contributing sufficiently to increase the noise level.

The top panel of Figure 3 shows the original temporal spectrum for all the data (Group I; left panels) as well as for just the MDM data (Group V; right panels). The middle panels show the residuals after prewhitening by the highest two peaks and the bottom panels are after prewhitening by the highest six peaks. Though some power remains in the Fourier transform (FT), and we could continue prewhitening, the peaks are conspicuously close to previously prewhitened frequencies and may be due to amplitude variation over the course of the data run. To investigate this possibility, Figure 4 shows the amplitudes of the four reasonably separated modes over the course of our observations. (The doublet cannot be separated in individual runs, so we do not fit it.) As anticipated, the frequencies with the largest residuals in Fig. 3 show the largest amount of variability in their amplitudes (left panel) while

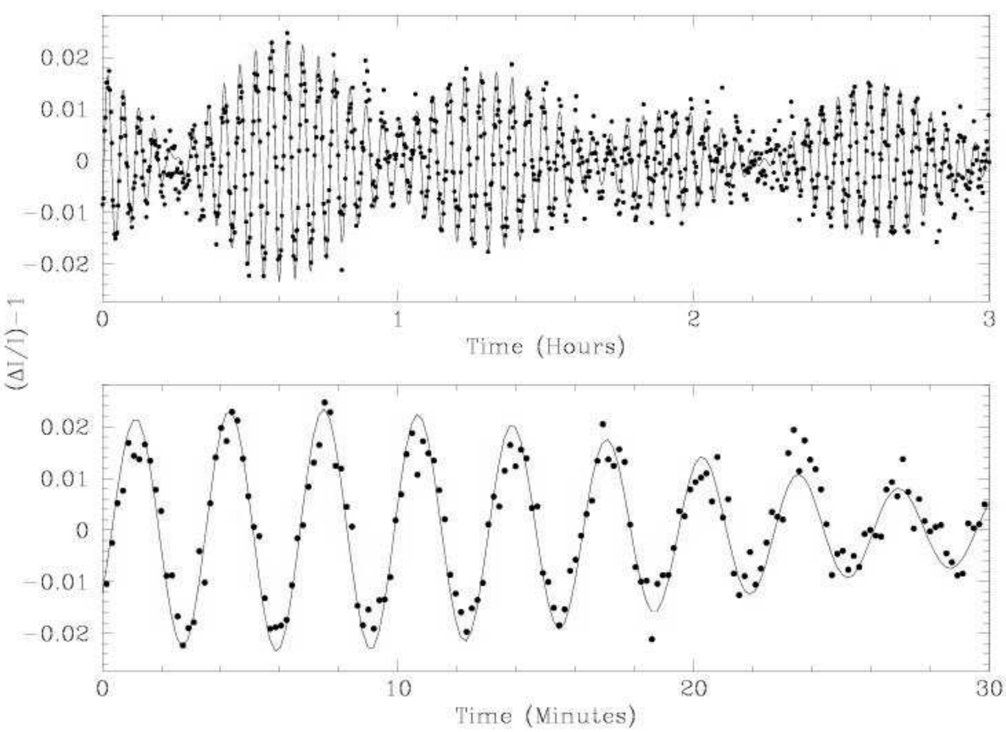



**Figure 1.** Lightcurves for KPD 2109 obtained at MDM observatory, plotted on two different time scales. The top panel shows 3 hours of data in which the beating is obvious. The bottom panel shows 30 minutes of data to emphasize individual pulsations. Solid line is the least-squares solution.

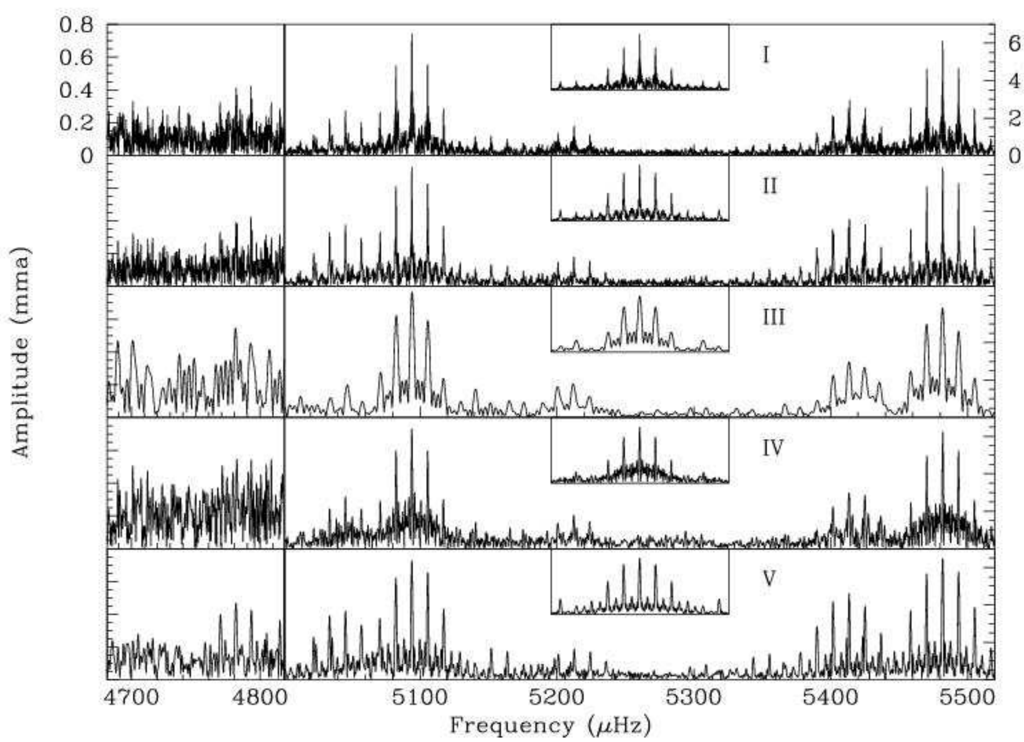



**Figure 2.** Temporal spectra of KPD 2109 for the groups in Table 2. Note that only regions with pulsations are included and that the scales for the left and right panels are different. Insets are the spectral windows with horizontal scales to match the right panels.

**Table 1.** Observations of KPD 2109+4401

| Run | Length (Hrs) | Date UT | Observatory | Run | Length (Hrs) | Date UT | Observatory |
|---|---|---|---|---|---|---|---|
| grc040912 | 9.5 | 12 Sept. | Athens 0.4m | bak092804 | 8.4 | 28 Sept. | Baker 0.4m |
| grc040913 | 3.6 | 13 Sept. | Athens 0.4m | bak092904 | 0.5 | 29 Sept. | Baker 0.4m |
| grc040914 | 5.6 | 14 Sept. | Athens 0.4m | bak093004 | 7.3 | 30 Sept. | Baker 0.4m |
| mdr269 | 8.4 | 14 Sept. | McDonald 2.1m | bak100304 | 7.9 | 3 Oct. | Baker 0.4m |
| grc040915 | 3.5 | 15 Sept. | Athens 0.4m | mdr274 | 5.6 | 5 Oct. | MDM 1.3m |
| mdr270 | 8.8 | 15 Sept. | McDonald 2.1m | mdr276 | 6.3 | 6 Oct. | MDM 1.3m |
| mdr271 | 8.7 | 16 Sept. | McDonald 2.1m | mdr278 | 6.5 | 7 Oct. | MDM 1.3m |
| mdr272 | 8.3 | 17 Sept. | McDonald 2.1m | mdr280 | 6.8 | 8 Oct. | MDM 1.3m |
| suh040918 | 6.8 | 18 Sept. | Suhora 0.6m | mdr282 | 6.5 | 9 Oct. | MDM 1.3m |
| mdr273 | 3.1 | 19 Sept. | Baker 0.4m | mdr284 | 2.0 | 10 Oct. | MDM 1.3m |
| bak092104 | 8.5 | 21 Sept. | Baker 0.4m | mdr287 | 6.5 | 11 Oct. | MDM 1.3m |
| bak092204 | 8.3 | 22 Sept. | Baker 0.4m | mdr289 | 1.7 | 12 Oct. | MDM 1.3m |
| bak092304 | 8.5 | 23 Sept. | Baker 0.4m | mdr292 | 6.3 | 13 Oct. | MDM 1.3m |
| bak092604 | 8.4 | 26 Sept. | Baker 0.4m | mdr294 | 1.8 | 14 Oct. | MDM 1.3m |
| bak092704 | 8.5 | 27 Sept. | Baker 0.4m | | | | |

**Table 3.** Comparison of pulsations detected in the various groups. Formal least-squares errors are provided in parentheses.

| Group | $f1$ | $f2$ | $f3$ | $f4$ | $f5$ | $f6$ |
|---|---|---|---|---|---|---|
| I | 5481.819(3) | 5413.819(6) | 5413.002(7) | 5212.604(10) | 5093.981(2) | 5045.466(8) |
| II | 5481.819(2) | 5413.818(6) | 5413.000(7) | 5212.592(10) | 5093.974(2) | 5045.427(22) |
| III | 5481.804(41) | 5413.269(80)$^{\dagger}$ | – | 5212.497(155) | 5094.189(37) | 5033.632(271)$^{\star}$ |
| IV | 5481.831(14) | 5413.460(31)$^{\dagger}$ | – | 5212.430(47) | 5093.986(15) | 5045.505(45) |
| V | 5481.811(11) | 5413.484(17)$^{\dagger}$ | – | 5212.629(41) | 5093.964(12) | 5045.504(20) |
| K98 | 5481.76 | 5413.62 | 5412.69 | 5212.42 | 5093.93 | 5045.54 |

$^{\dagger}$ The doublet is unresolved in these Groups.
$^{\star}$ Indicates modes offset by approximately the daily alias (11.56 $\mu$Hz).

the phases remain within 20% of their original value. This indicates that the amplitude variability is intrinsic to the pulsations rather than due to beating between closely spaced modes. As prewhitening removes a constant-amplitude sine curve from the data, it sometimes overestimates and at other times underestimates the amplitudes. The net effect is that prewhitening does not remove all of the power, leaving the residuals in the bottom panel of Figure 3. The right panel of that figure is just for the MDM data and indicates that over the shorter time span, the amplitude variations are less, so prewhitening does a better job and the residuals are correspondingly smaller. This indicates that we have likely resolved the pulsation spectrum of KPD 2109. Our least-squares solution for the entire data set which is provided in Table 4.

**Table 4.** Non-linear least-squares solution to the entire data set. Formal least-squares errors are in parentheses.

| Label | Period (sec) | Frequency ($\mu$Hz) | Amplitude (mma) |
|---|---|---|---|
| $f1$ | 182.42120(8) | 5481.819(3) | 6.13(9) |
| $f2$ | 184.71248(23) | 5413.819(6) | 2.63(10) |
| $f3$ | 184.74037(25) | 5413.002(7) | 2.32(10) |
| $f4$ | 191.84271(36) | 5212.604(10) | 1.63(9) |
| $f5$ | 196.31012(10) | 5093.981(2) | 6.44(9) |
| $f6$ | 198.19774(30) | 5045.466(8) | 2.03(9) |
| $f7$ | 209.14104(20)$^{\dagger}$ | 4781.462(45) | 0.35(9) |
| $f8$ | 212.71520(22)$^{\dagger}$ | 4701.122(49) | 0.32(9) |

$^{\dagger}$ These frequencies are only above the detection threshold in the MDM and McDonald data.

## 4 DISCUSSION

### 4.1 Multiplet constraints on pulsation modes

A simple test is to examine the data for constant spacings between frequencies. Such multiplet structure can be used to constrain the degree, $\ell$, of the spherical harmonics that describe the pulsation geometry on the stellar surface (Winget et al. 1991). Even a cursory glance at our observed frequencies indicates that no two splittings are close to evenly spaced. Combined with a spectroscopic constraint on the rotation velocity of $v \sin i \leq 10\,\mathrm{km\,s^{-1}}$ (Heber, Reid, & Werner 2000), we are left with three possibilities: 1) Rotation is sufficiently slow that differing $m$ values are degenerate; 2) our line of sight is along the pulsation axis, with $\sin i \approx 0$, making only $m = 0$ modes observable because of geometric cancellation (Pesnell 1985); or 3) internal rotation is such that even though the external (spectroscopic) rotation is slow, rotationally-induced multiplets are widely spaced and uneven (Kawaler & Hostler 2005).

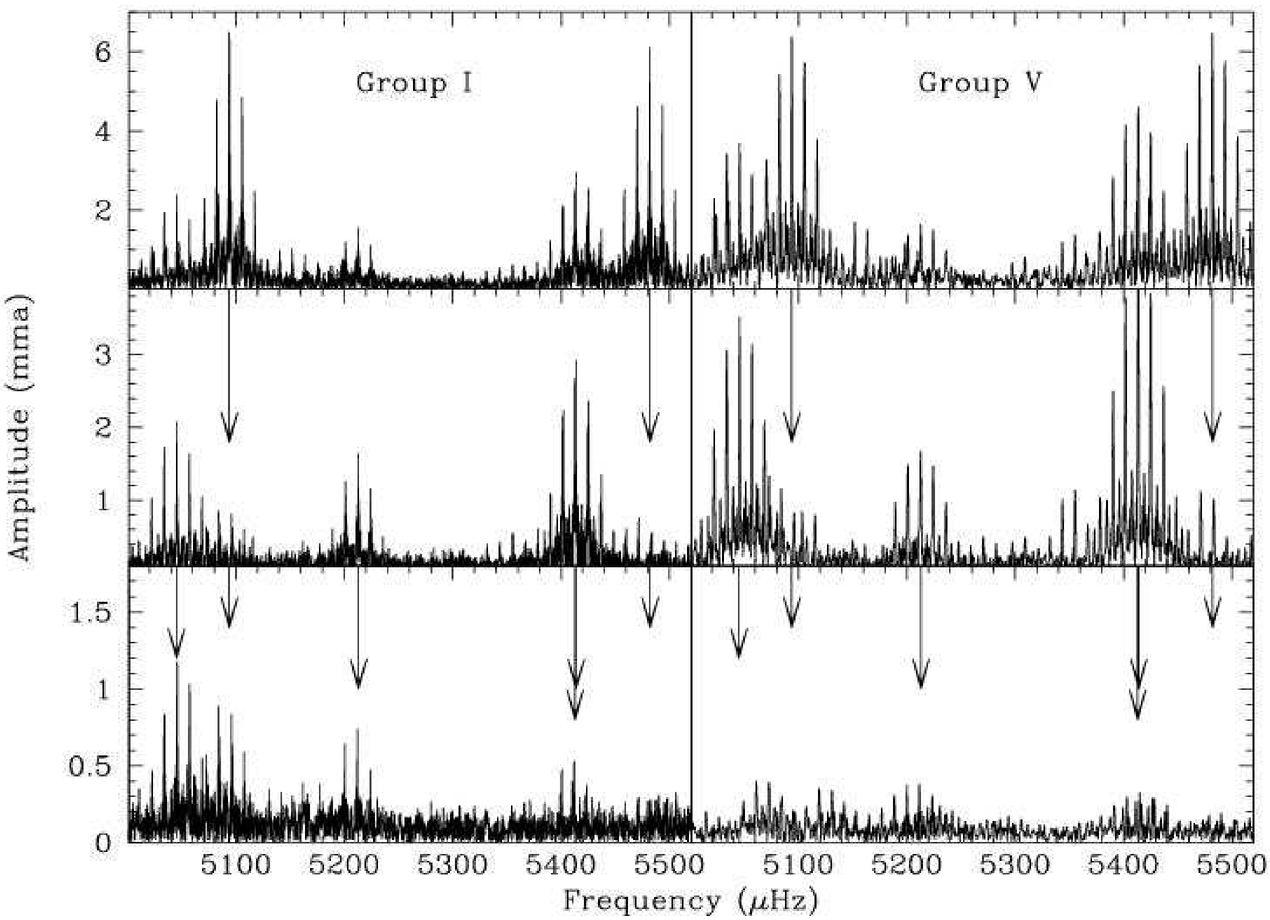


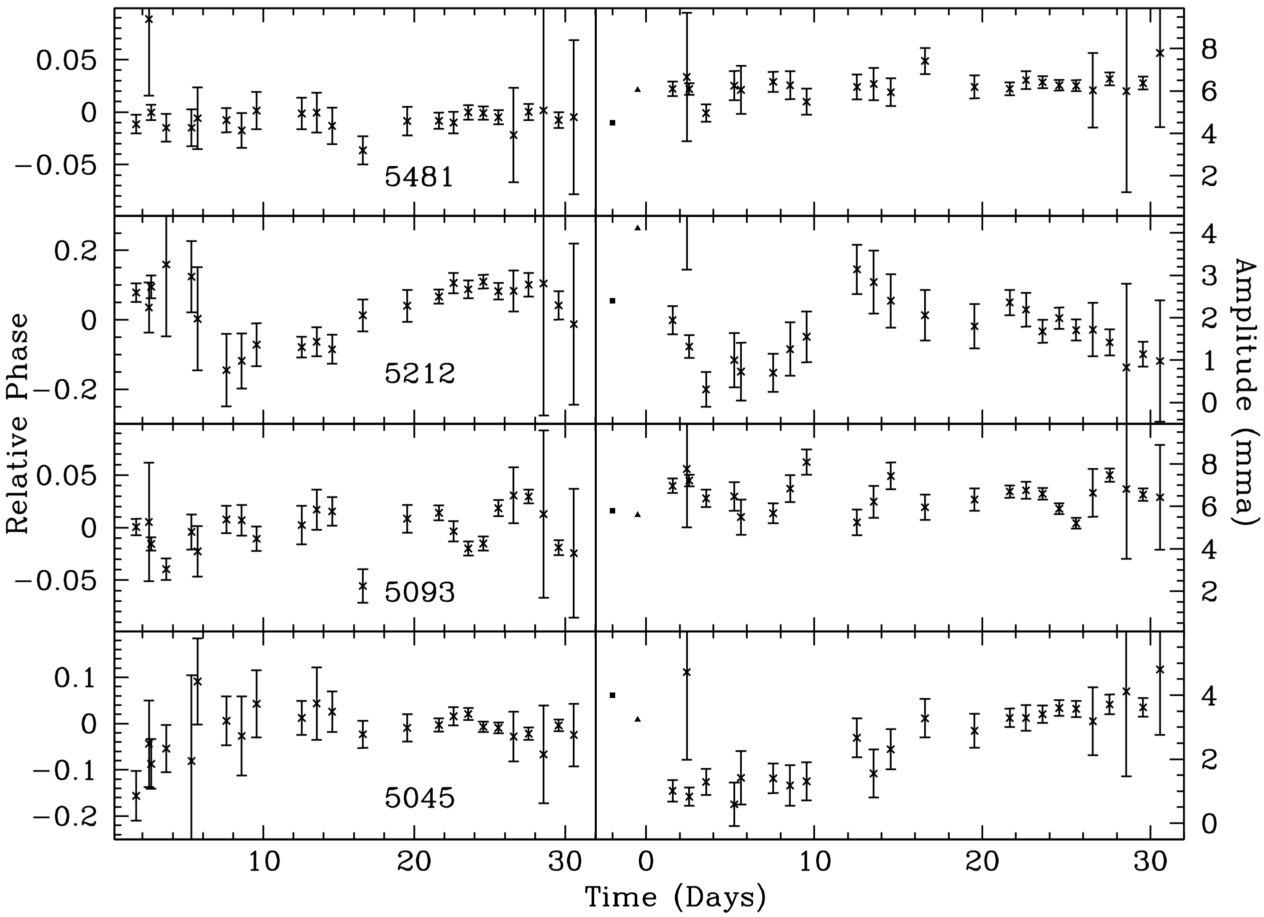

**Figure 3.** Sequence of prewhitening for Groups I and V data. Top panels: Original Fourier transforms. Middle panels: Prewhitened by the highest 2 peaks. Bottom panels: Prewhitened by all 6 frequencies in Table 3.

### 4.2 Amplitude variability

Since we are relatively confident that our data have resolved the pulsation spectrum of KPD 2109, we can examine several features of the pulsations themselves. If sdBV stars are observed over an extended time period, it is common to detect amplitude variability in many, if not all, of the pulsation frequencies. Such variability can occasionally be ascribed to pulsations too closely spaced to be resolved in any subsets of the data, but often appear in clearly resolved pulsation spectra where it cannot be ascribed to mode beating. PG 1605+072 is perhaps the most complex sdBV star, pulsating in over 55 frequencies. However, it also has the highest amplitude pulsations and over several years of observations, the main peaks do not stay at the same amplitudes, or even at the same frequencies (O'Toole et al. 2002). PG 1336-018 was observed to have pulsation amplitudes that changed on a daily basis during a multisite campaign (Kilkenny et al. 2004). Feige 48 and PG 1219+534 both have simple, readily-resolved pulsation spectra that show clear amplitude variations over the course of months to years (Reed et al. 2004; Harms, Reed, & O'Toole 2005).

Figure 4 shows the amplitudes and phases of the 4 frequencies which are sufficiently resolved and detectable on a nightly basis. As our campaign covers 32 nights, we can readily detect small changes in amplitude that over time form trends but which might go unnoticed in shorter runs. Additionally, we can use this information for detecting systematic differences in data between observatories. Though there was one Athens run (night 3) that was very noisy and two MDM runs (nights 28 and 30) that were very short, and thus have large errors, there are no trends between observatories, indicating that timing and amplitudes were not adversely impacted by using the different telescopes. For KPD 2109, $f1$ and $f5$ clearly appear stable over our time scale. Neither the amplitude or phase changes substantially. The amplitude of $f4$ nearly vanishes around day 2 of our run(JD=2453249) with a peak amplitude of $\approx 3$ mma on day 12. Interestingly, the corresponding phase varies by about 40% and looks nearly sinusoidal, though we do not know why this should be. However, as the phase becomes less precise around amplitude minimum, it may just be a happenstance artifact of the data. While the phases for $f6$ appear essentially stable, the amplitude clearly increases steadily over the span of our run; more than doubling in magnitude. As such, KPD 2109 presents itself as an interesting case with two very stable modes and two that obviously vary in

**Figure 4.** Phases and amplitudes of the four well-separated frequencies over the course of our observations. Frequencies are indicated in each panel. Phases are calculated as time of first maximum after JD=2453249.5 divided by the period. Amplitudes from K98 and J04 are also provided (as filled squares and triangles, respectively).




amplitude with at least one of these varying significantly in phase as well. We cannot readily discuss the $f2$ - $f3$ doublet as we cannot resolve them in individual runs and $f7$ and $f8$ are not detected sufficiently to examine their amplitudes or phases. Included in Fig. 4 are the amplitudes determined by K98 (filled squares) and J04 (filled triangles) for the four frequencies shown. Except for the J04 amplitude for the 5212 $\mu$Hz frequency, they are consistent with what we find. There are no obvious longer–period trends, though these would be difficult to find considering the amplitude variability within our 32 night data set.

### 4.3 The nature of the excitation mechanism

We can also use the criterion outlined in Pereira & Lopes (2005) to examine the nature of the excitation mechanism. If the frequencies are stochastically excited, we can expect to find the standard deviation of the amplitudes, $\sigma(A)$, divided by the average amplitude $\langle A\rangle$ to have a value near 0.5 (Eqn. 7 of Pereira & Lopes 2005). Both parameters and their ratio for the frequencies in Fig. 4 are given in Table 5. As might be expected based solely on their amplitudes, $f1$ and $f5$ have very small ratios indicative of non-stochastically excited modes while $f6$ almost exactly fits the criterion for stochastically excited pulsations. Frequency $f4$ is slightly ambiguous; appearing near-enough to 0.5 to make its support of stochastic excitation conceivable, but not convincing.

**Table 5.** Standard deviation and mean amplitude for four readily resolvable frequencies.

| Frequency ($\mu$Hz) | $\sigma(A)$ (mma) | $\langle A\rangle$ (mma) | $\sigma(A)/\langle A\rangle$ |
|---|---|---|---|
| 5481 | 6.20 | 0.45 | 0.07 |
| 5212 | 1.68 | 0.72 | 0.43 |
| 5093 | 6.49 | 0.75 | 0.12 |
| 5045 | 2.37 | 0.12 | 0.51 |

### 4.4 Constraints on pulsation degree via mode density

Another question involving sdBV stars is the mode degree $\ell$ of the pulsations. In resolved sdBV stars, we sometimes observe many more pulsation modes than $\ell$=0, 1, and 2 can provide. Higher $\ell$ modes may be needed, but if so they must

have a larger intrinsic amplitude because of the large degree of geometric cancellation (Charpinet et al. 2005; Reed, Brondel, & Kawaler 2005). From the lack of multiplet structure we may assume that all $m$ values are degenerate and only concern ourselves with the number of $\ell$ modes available within the observed frequency limits of KPD 2109. Not attempting to match frequencies, but merely choosing a representative model based on $\log g$ and $T_{\rm eff}$ from spectroscopy (Heber et al. 2000), we can determine if a model can provide the observed mode density using only $\ell$=0, 1, and 2 modes. We searched our model grid of ISUEVO models (see Reed et al. 2004) within the spectroscopic error box of KPD 2109. The minimum distance between consecutive orders for the same $\ell$ was $\approx 1050\mu$Hz with a median spacing of $\approx 1200\mu$Hz for $\ell$=0, 1, or 2. We also examined a representative model from the published grid by Charpinet et al. (2002; model # 7 with $T_{\rm eff}$ = 31311 K and $\log g$ = 5.75). The spacings between their consecutive orders near the appropriate frequency range for KPD 2109 was 892, 1413, 575, and 949 $\mu$Hz for $\ell$=0, 1, 2, and 3, respectively. As the observed range between $f1$ and $f6$ is only $\approx 500\,\mu$Hz, models can only supply a single frequency per $\ell$ degree. To obtain the number of frequencies observed in KPD 2109, assuming no rotational splitting, would require $\ell$ values up to 5. Thus we can add KPD 2109 to the list of sdBV stars with pulsations too dense to be accounted for with only low-degree ($\ell \leq 2$) modes.

### 4.5 Comparison with multicolour photometry

As part of the discovery data, K98 obtained 4 nights (spread over 6 days and totaling 26.6 hours) of simultaneous 4-color (UBVR) observations of KPD 2109 and in 2002, three consecutive nights of ULTRACAM data (totaling 9.7 hours) were obtained by Jeffery et al. (2004; hereafter J04). We have frequencies $f1$ - $f6$ in common with K98 who, using unconstrained and adiabatically constrained phases identifies $\ell$= 1, 2, 2, 2, 2, 1 and 1, 0, 2, 2, 2, 1 respectively. We have $f1$, $f2$, $f4$, $f5$, and $f6$ in common with J04 who identifies these frequencies as $\ell$= 0, 2, 1, 0, and 2. Interestingly, J04 identifies the 5084 $\mu$Hz frequency detected in K98 as $\ell$=4. However, we again (and disappointingly) have to dismiss this frequency as undetectable in the J04 data set. J04 were unable to simultaneously fit all of their data with their frequency solutions because of the complexity of the data window. However, for their 3 individual runs, the frequency resolutions are 245, 153, and 40 $\mu$Hz, respectively; far too large to distinguish the 5084 $\mu$Hz frequency from the much higher amplitude 5093 $\mu$Hz one. The final result is that none of the frequencies have the same $\ell$ value in all three determinations and none of the reliably detected frequencies indicate $\ell$ values larger than 2, though such values are required to match the frequency density given current models.

## 5 CONCLUSIONS

Based on the extensive data acquired from five observatories, we are able to resolve the pulsation spectrum of the pulsating sdB star KPD 2109+4401. We have analyzed the entire data set as well as several subsets to insure that we have detected real peaks rather than aliases. We confirmed the five known frequencies $f1 - f5$ previously identified by both K98 and Billéres et al. (1998), but do not detect the 5084 $\mu$Hz frequency detected by K98. We suspect that as this frequency was the lowest amplitude pulsation detected by K98, the amplitudes showed some variability in his data, and since it must have been somewhat masked by the window pattern (see Fig. 4 of K98), that it was likely an artifact of his data. Of course another possibility is that the amplitude has since diminished beyond our detection limit. We resolve a doublet ($f2$ and $f3$) also detected by K98, but at 0.8 $\mu$Hz separation, was not readily resolvable in his data. Furthermore, our best data sets detect the feature at 4781 $\mu$Hz, which was suspected by K98 and marginally detect another frequency at 4701 $\mu$Hz.

As shown in Fig. 2 and provided in Table 3, all of our subsets detect the same frequencies without ambiguity, though the doublet is only resolved in Groups I and II. The detection of the two low-amplitude frequencies ($f8$ and $f9$) relies on the high S/N data from larger telescopes; here the MDM 1.3-m and the McDonald 2.1-m telescopes. We have shown that even though there is residual power in the FT after prewhitening by the six main frequencies, it is almost certainly caused by amplitude variation.

We have examined our frequency content for observational constraints on the pulsation modes with the following results, and detect no signs of evenly spaced frequency multiplets that could be induced by rotation. As such, we have no way to distinguish between pulsation frequencies of varying $m$ values and assume that they are degenerate, or $m = 0$. Current models cannot reproduce the observed frequency density without invoking high-degree ($\ell \geq 3$) modes. However, multicolour photometry constrains all observed frequencies to $\ell \leq 2$, though the identifications for individual frequencies disagree between methods and observers.

We examined pulsation amplitudes of the four frequencies that are resolvable on a night-by-night basis over the duration of our run and notice that two frequencies are stable while two vary substantially. The amount of amplitude variability can be used to test if the pulsations are of a stochastic nature and we determine that two frequencies are definitely not stochastically excited while the two amplitude-variable frequencies could be.

Our scientific goal of this observational study was to resolve the pulsation structure of the sdB star KPD 2109 by combining limited amounts of data from larger telescopes with data from smaller ($\sim$0.5 m) telescopes. As expected, this combination has allowed us a long timebase sufficient to resolve closely spaced pulsations of the star and the increased S/N of the larger telescopes allow us to detect pulsations with amplitudes as low as 0.3 mma. These data are five times better than K98 in resolution and three times more sensitive in amplitude. These successful efforts encourage us to carry out detailed follow-up observations for other poorly studied stars of this class.

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